CBCT Brain Perfusion:
Phantom and Digital Simulator

Computer Integrated Surgery II

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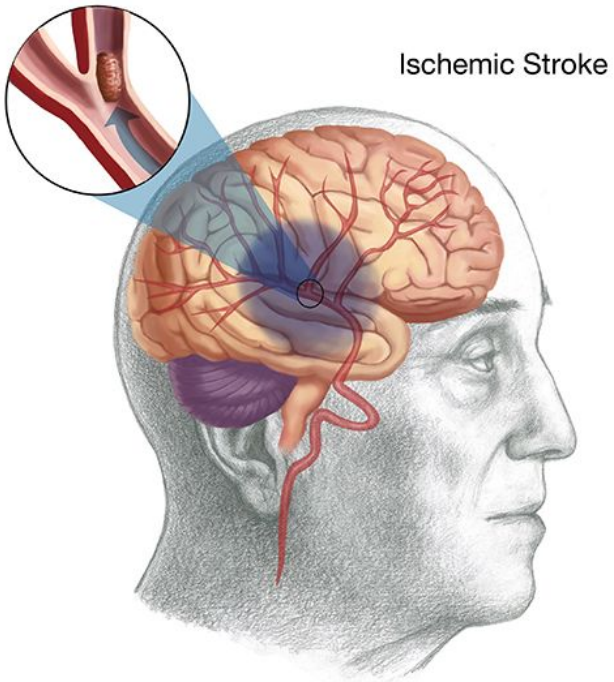
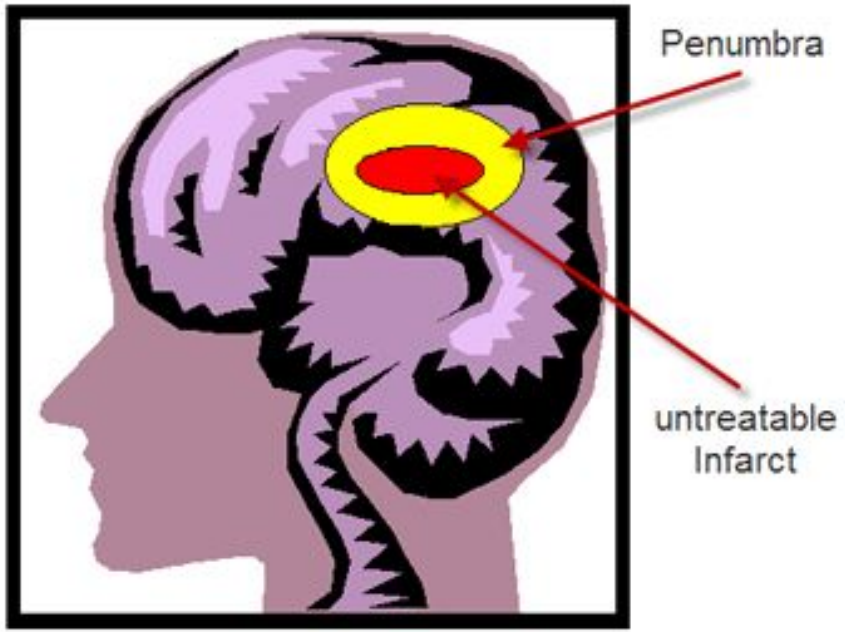
Project Motivation and Relevance

- Acute stroke is the third leading cause of death in the US (approximately 1 in 15 deaths)
- The recoverable time window is a matter of hours, making speed a priority.
- There is a pressing need for fast, accurate detection and evaluation of acute stroke



Project Motivation and Relevance

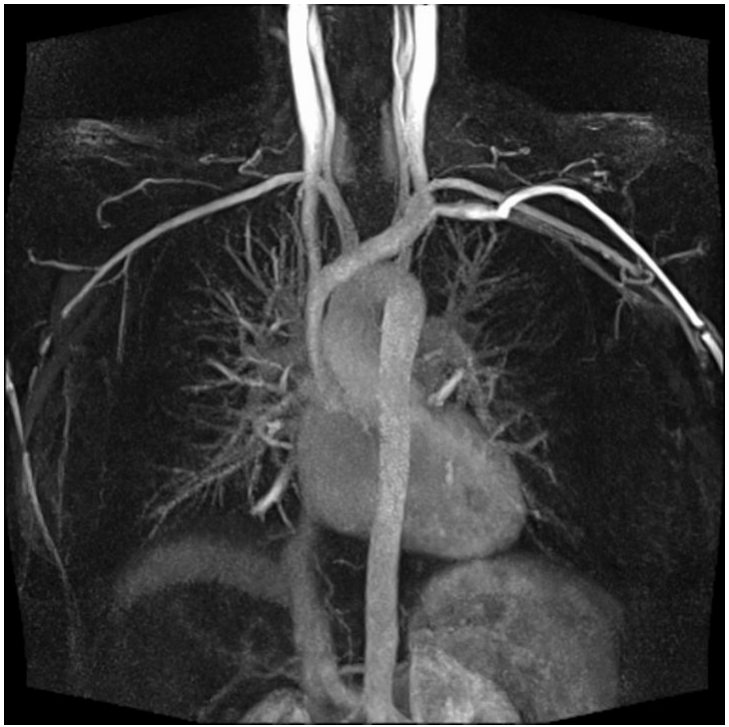
- A dedicated Cone-Beam Computed Tomography (CBCT) scanner for the detection and evaluation of intracranial hemorrhage (ICH) is being developed at JHMI
- Diagnosis of ischemic stroke, as opposed to hemorrhagic stroke requires contrast enhanced CT perfusion images, aiming to answer two questions of imaging acute stroke:
  - Is there an **ischemic core** of critically irreversibly infarcted tissue?
  - Is there a "**penumbra**" of severely ischemic but recoverable tissue?

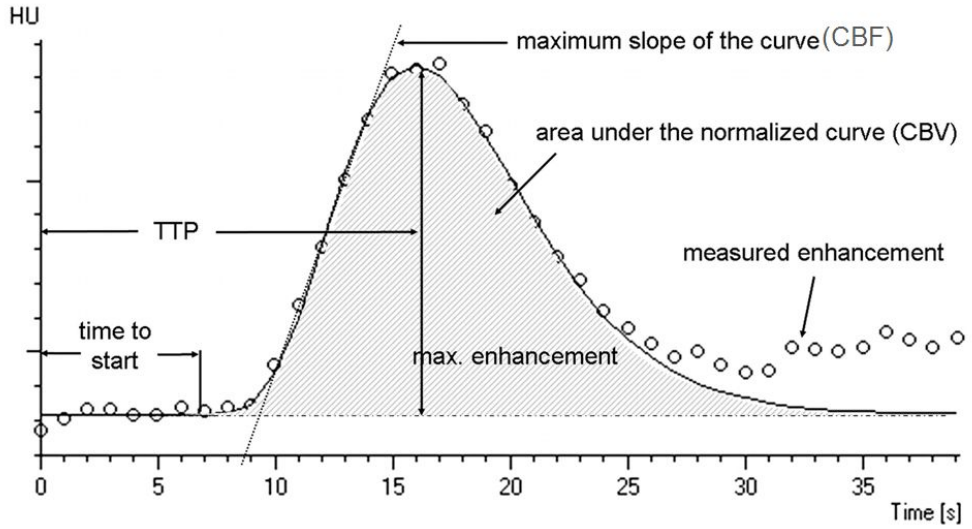


Mission/Project Goal

Our aim is to evaluate the feasibility of CBCT scanner in conjunction with perfusion imaging by constructing a digital and physical phantom to reliably characterize perfusion parameters among a wide range of ischemic stroke cases.

Perfusion Imaging



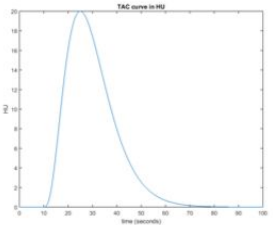


Technical Approach for Digital Phantom

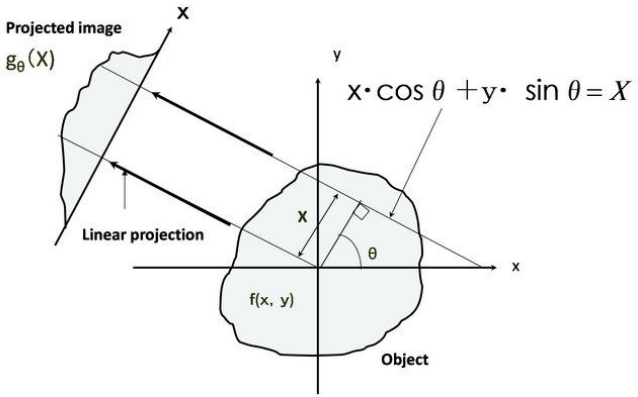
Time Attenuation Curve

+

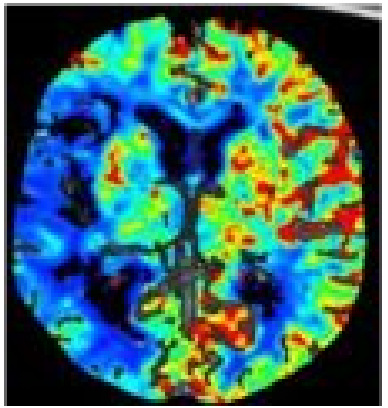
Head Phantom



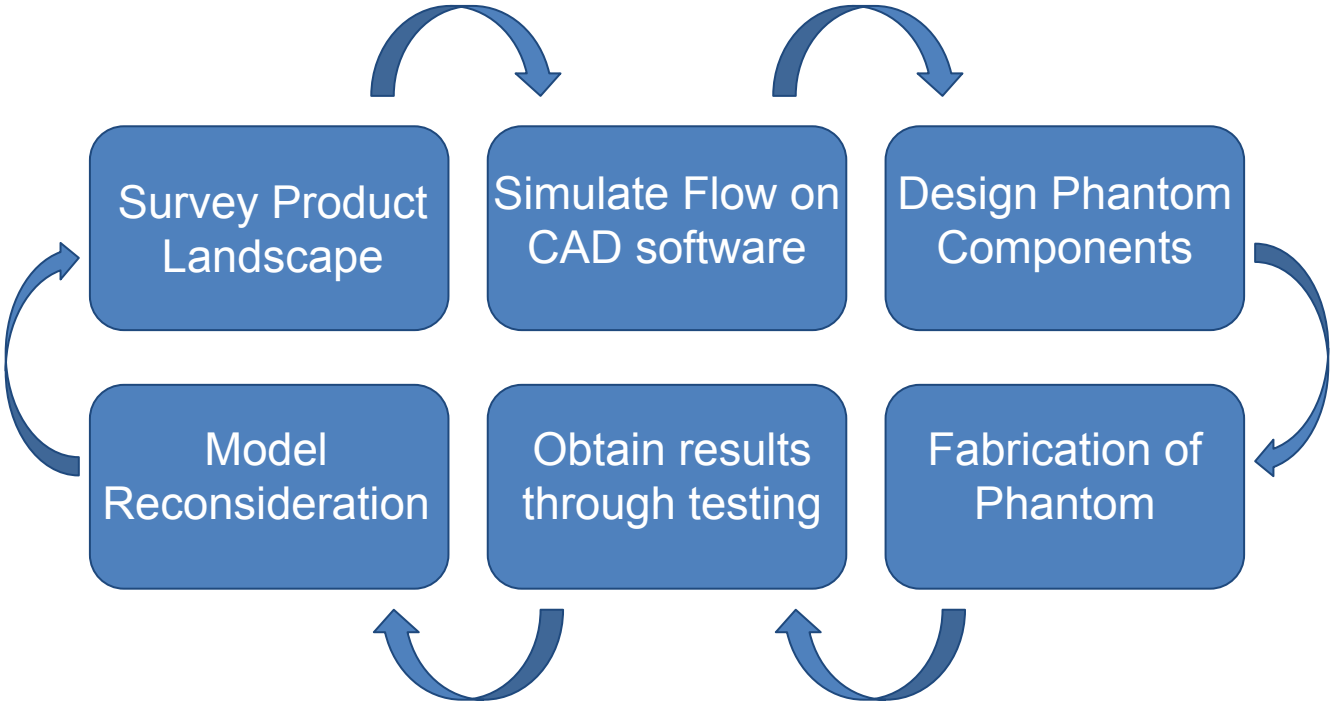
→ Forward Projection →

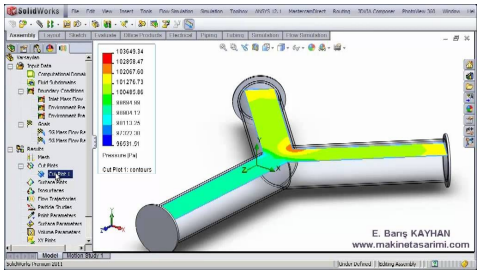


→ Reconstruction

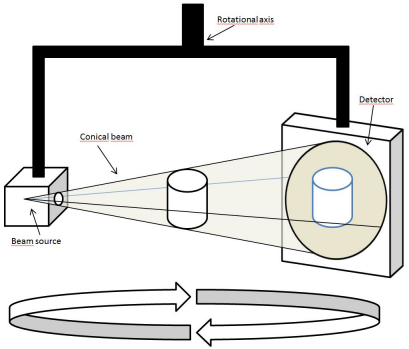


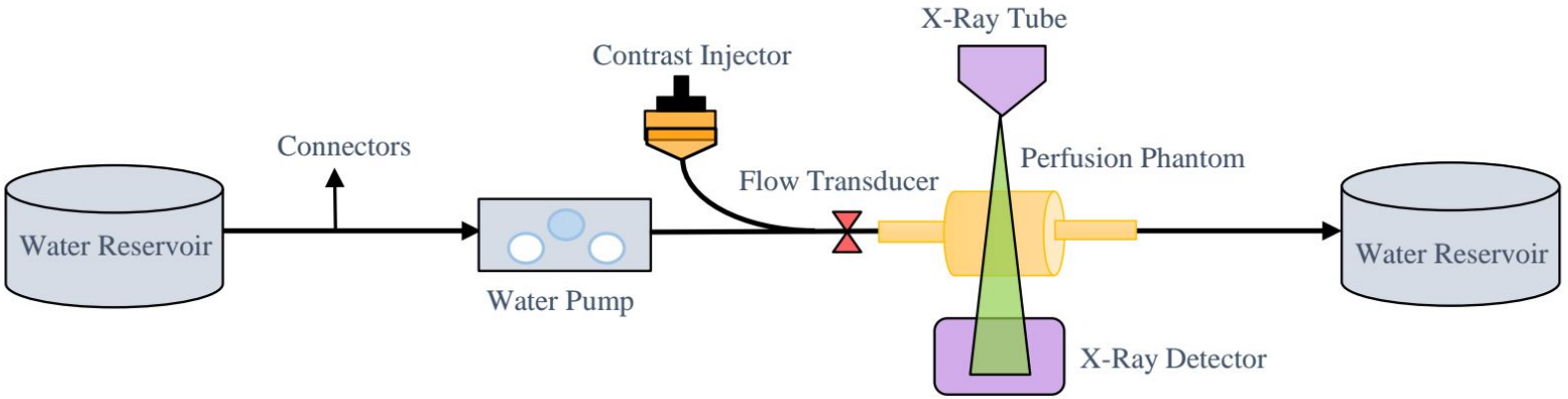
Design Approach for Physical Phantom





Design Approach of Physical Phantom





Deliverables

Minimum

- Generate time attenuation curves for a wide range of stroke cases
- Complete a forward projection and reconstruction of a region of interest in the digital head phantom
- Perform validation by testing entire range of scan speeds and corresponding impact on accuracy

Expected

- Survey existing product landscape
- Develop flow models using CAD software
- Design and fabricate physical phantom
- Develop control system to derive optimal input parameters for specified perfusion parameters

Maximum

- Thorough testing and measurements of time attenuation profiles and perfusion parameters in the phantom
- Submission to conference

Dependencies

Dependencies for Digital Phantom

- Access to a GPU Workstation (Met)
  - If Workstation fails, access to various other GPU workstations in I-STAR lab through remote desktop (Met)
- Access to CUDA Tools (Met)
- Digital Brain Phantom (Met)

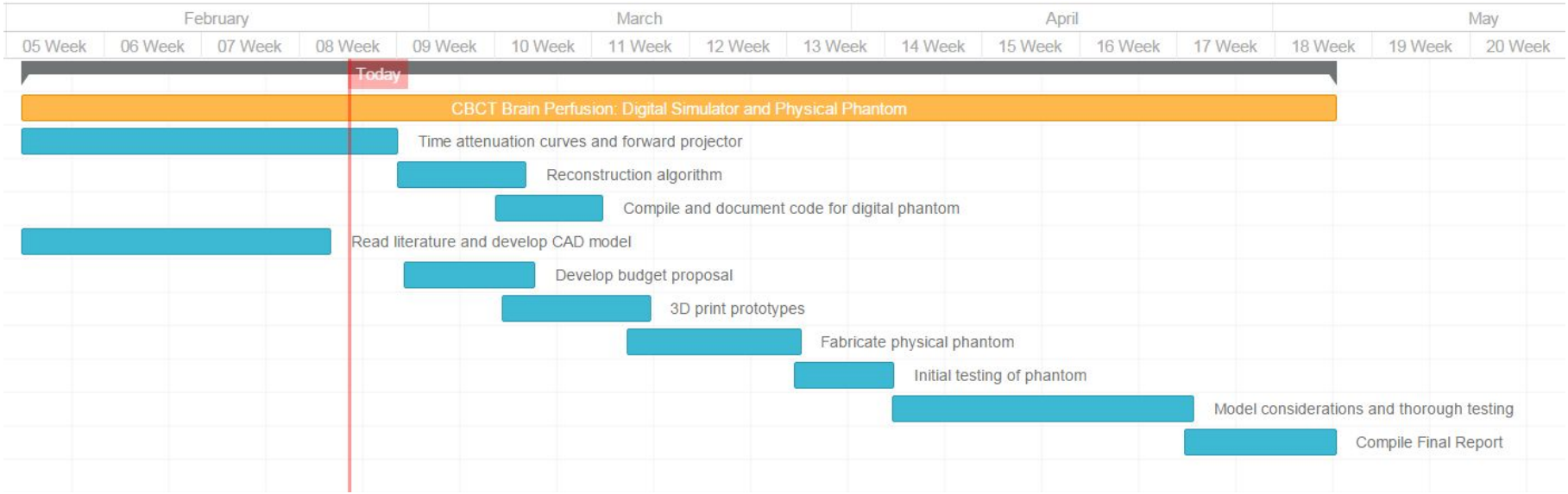
Dependencies for Physical Phantom

- Access and training for 3D Printer in Carnegie at JHMI (Met)
  - If 3D printer breaks or becomes unavailable, other options include fabrication at the JHU BME Design Studio, the JHU Digital Media Center, or outsource to other makerspace
- Access and training for machine shop at JHMI (Unmet, training will take place in March)
  - Other options for machine shop access may include Wyman Park Building machine shop or outsourced components
- Access to a CT scanner for testing (Met)
  - If CT bench in I-STAR lab breaks or becomes unavailable, we will consult our advisors about finding a substitute facility such as a clinical CT scanner

Advising Dependencies

- Funding for physical phantom component (Met)
  - We have obtained verbal agreement for funding from our advisors
- Availability of collaborators (Met)
  - We have arranged weekly meetings on Monday mornings with our advisors to obtain feedback and advice towards completing our project.

Timeline


February
March
April
May
05 Week
06 Week
07 Week
08 Week
09 Week
10 Week
11 Week
12 Week
13 Week
14 Week
15 Week
16 Week
17 Week
18 Week
19 Week
20 Week
Today
CBCT Brain Perfusion: Digital Simulator and Physical Phantom
Time attenuation curves and forward projector
Reconstruction algorithm
Compile and document code for digital phantom
Read literature and develop CAD model
Develop budget proposal
3D print prototypes
Fabricate physical phantom
Initial testing of phantom
Model considerations and thorough testing
Compile Final Report

Milestones

February 25: Finalize Literature Review
February 25: Submit proposal documents
February 29: Complete forward projection for digital phantom
March 7: Complete reconstruction algorithm for digital phantom
March 7: Propose Budget and Begin ordering Parts
March 14: Finalize digital phantom (**Minimum Deliverable**)
March 14-21: Spring Break
March 28: Finalize design of physical phantom (**Expected Deliverable**)
April 25: Complete testing and standardization of the physical phantom (**Maximum Deliverable**)
May 06: Final report Presentation

Management Plan

Karthik	Michael
Lead proposal of physical phantom	Lead design of digital simulator
Extensive survey of existing product landscape	MATLAB implementation using CudaTools
Phantom testing protocol	MATLAB code documentation
Administrative Operations (i.e. Budget Proposal, BitBucket management, etc.)	Fabrication of phantom
Develop CAD/flow simulation Design physical phantom component layout	

Reading List

Boese, A., Gugel, S., Serowy, S., Purmann, J., Rose, G., Beuing, O., … Deuerling-Zheng, Y. (2013). Performance evaluation of a C-Arm CT perfusion phantom. *International Journal of Computer Assisted Radiology and Surgery*, *8*(5), 799–807. http://doi.org/10.1007/s11548-012-0804-4

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